MAGNETORESISTANCE EFFECT DEVICE WITH A TA, HF, OR ZR SUBLAYER CONTACTING AN NIFE LAYER IN A MAGNETO RESISTIVE STRUCTURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention concerns a magnetoresistance effect device for reading information signals recorded on a magnetic storage medium, and a magnetoresistance effect sensor, magnetoresistance detection system, and magnetic storage system using the said device.

2. Description of the Related Art

Magnetic reading converters called magnetoresistance (MR) sensors and MR heads are known in the prior art. A characteristic of these devices is the ability to read data from magnetic storage medium surfaces at high linear density. An MR sensor detects magnetic field signals through resistance changes that are a function of the strength and direction of magnetic flux sensed by a reading device. Such MR sensors of the prior art operate on the anisotropic magnetoresistance (AMR) effect whereby one component of the resistance of the reading device varies as the square of the cosine of the angle subtended by the magnetization direction and the direction of sensed electric current flowing through the device. A more detailed treatment of the AMR effect is set forth in the monograph of D. A. Thompson et al. entitled "Memory, Storage, and Related Applications" in *IEEE Trans. on Mag. MAG*-11, p. 1039 (1975). With magnetic heads that use the AMR effect, vertical bias is often applied to suppress Barkhausen noise. The material used for applying this vertical bias is sometimes an antiferromagnetic material such as FeMn, NiMn, or a nickel oxide.

Recently, moreover, there have been reports of a more pronounced magnetoresistance effect wherewith resistance variation in a laminated magnetic sensor is attributable to the spin-dependent transmission of conduction electrons between ferromagnetic layers on either side of a nonmagnetic layer, and to spin-dependent scattering at the interfaces incidental thereto. This magnetoresistance effect is called by such names as the "mega-magnetoresistance effect" or the "spin valve effect." Such MR sensors are made of suitable materials and exhibit improved sensitivity and larger resistance variation when compared to what is observed in sensors employing the AMR effect. In this type of MR sensor, the resistance in the plane between the pair of ferromagnetic layers separated by the nonmagnetic layer varies in proportion to the cosine of the angle subtended by the magnetization directions of the two ferromagnetic layers. Laid-open patent application H2-61572 [1990] (gazette publication) discloses a laminated magnetic structure that brings about high MR variation which is produced by the anti-parallel alignment of magnetization in magnetic layers. In this gazette publication, ferromagnetic transition metals and alloys are listed as materials that can be used in the laminar structure. Also disclosed are a structure in which an antiferromagnetic layer is added to at least one of the two ferromagnetic layers separated by the intermediate layer, and that FeMn is suitable for the antiferromagnetic layer. Laid-open patent application H4-358310 [1992] (gazette publication) discloses an MR sensor that comprises two ferromagnetic layers partitioned by an antiferromagnetic layer, wherein the magnetization directions of the two ferromagnetic layers are mutually perpendicular when the applied magnetic field is zero, and wherein the resistance

between the two non-joined ferromagnetic layers varies in proportion to the cosine of the angle subtended by the magnetization directions of the two layers and is independent of the direction of current flow in the sensor. Laid-open patent application H6-203340 [1994] (gazette publication) discloses an MR sensor that is based on the effect noted above and that comprises two ferromagnetic layers separated by an antiferromagnetic layer, wherein, when the externally applied magnetic field is zero, the magnetization of adjacent antiferromagnetic layers is maintained perpendicular to the ferromagnetic layers. Laid-open patent application H7-262529 [1995] (gazette publication) discloses a magnetoresistance effect device that is a spin valve comprising a first magnetic layer/antimagnetic layer/second magnetic layer/antiferromagnetic layer structure, wherein the material used in the first and second magnetic layers is CoZrNb, CoZrMo, FeSiAl, FeSi, or NiFe, or any of these to which Cr, Mn, Pt, Ni, Cu, Ag, Al, Ti, Fe, Co, or Zn has been added. Laid-open patent application H7-202292 [1995] (gazette publication) discloses a magnetoresistance effect film comprising a plurality of soft magnetic thin films laminated on a substrate with intervening antiferromagnetic thin films, wherein an antiferromagnetic thin film is provided adjoining to one of the soft magnetic thin films that are mutually adjacent with an intervening antimagnetic thin film, wherein Hc**2**<Hr, where Hr is the bias magnetic field of the antiferromagnetic thin film and Hc**2** is the coercive force of the other soft magnetic thin films, and wherein the antiferromagnetic thin film is made of at least one of the substances NiO, CoO, FeO, Fe_2O_3, MnO, or Cr, or a mixture thereof. Laid-open patent applications H6-214837 [1994] and H6-269524 [1994] (gazette publications) disclose a magnetoresistance effect film that is the magnetoresistance effect film noted above wherein the antiferromagnetic thin film is a superlattice made of two or more substances selected from among NiO, $Ni_xCo_{1-x}O$, and CoO. Laid-open patent application H7-11354 [1995] (gazette publication) discloses a magnetoresistance effect film that is the magnetoresistance effect film noted above wherein the antiferromagnetic thin film is a superlattice made of two or more substances selected from among NiO, $Ni_xCo_{1-x}O$ (where x=0.1 to 0.9), and CoO, and wherein the atomic number ratio of Ni to Co is 1.0 or higher. And laid-open patent application H7-136670 [1995] (gazette publication) discloses a magnetoresistance effect film that is the magnetoresistance effect film noted above wherein the antiferromagnetic thin film is a two-layer film wherein CoO is laminated onto NiO to a thickness of from 10 to 40 angstroms.

On page 265 of the *Dai 20-kai Nihon Oyo Jiki Gakkai Gakujutsu Koenkai Gaiyoushu* (*Collected Abstracts From 20th Scientific Lecture Conference of Japan Society of Applied Magnetics*) there are reported examples of magnetoresistance effect films having the basic structure of sublayer/NiFe layer/CoFe layer/antimagnetic layer/fixed magnetic layer/antiferromagnetic layer, wherein Ta at a thickness of 50 angstroms is used for the sublayer, NiFe at a thickness of 35 Å is used for the NiFe layer, $Co_{90}Fe_{10}$ at a thickness of 40 Å is used for the CoFe layer, Cu at a thickness of 32 Å is used for the antimagnetic layer, $Co_{90}Fe_{10}$ at a thickness of 40 Å is used for the third antiferromagnetic layer, and FeMn at a thickness of 100 Å is used for the antiferromagnetic layer. In the fabrication process for the magnetoresistance effect devices having the basic structure of sublayer/NiFe layer/CoFe layer/antimagnetic layer/fixed magnetic layer/antiferromagnetic layer in-the prior art, in many cases, heat treatment at or above 200° C. is necessary in order to impart an exchange